

Applicant: Williams et al.
For: Apparatus and Method for Measuring the Mass of a Substance

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1 1. An apparatus for measuring the mass of a substance comprising:
2 a sensor having a membrane layer, the membrane for receiving the
3 substance thereon;
4 an oscillator device for driving said membrane at a reference resonant
5 frequency;
6 a frequency detection device for determining a change in the reference
7 resonant frequency caused by the presence of the substance on the membrane; and
8 a mass determining device for determining the mass of the substance, the
9 amount of change in the reference resonant frequency being indicative of the mass of the
10 substance.

1 2. The apparatus of claim 1 wherein said sensor is a flexural plate wave sensor.

1 3. The apparatus of claim 2 wherein said flexural plate wave sensor is formed
2 from a silicon substrate and said membrane is formed from a silicon layer.

1 4. The apparatus of claim 3 wherein said flexural plate wave sensor further
2 includes a piezoelectric layer formed on said membrane, a first transducer disposed on said
3 piezoelectric layer and a second transducer disposed on said piezoelectric layer, spaced
4 from said first transducer.

1 5. The apparatus of claim 4 wherein said oscillator device is connected to said
2 first transducer for driving said membrane at said reference resonant frequency and said
3 frequency detection device is connected to said second transducer for determining the
4 change in said reference frequency.

1 6. The apparatus of claim 1 wherein said sensor further includes a plurality of
2 walls peripheral to said membrane, said plurality of walls cooperating to define a cavity
3 having said membrane as a bottom portion thereof.

1 7. The apparatus of claim 1 wherein the deposition of the substance on the
2 membrane causes a decrease in the reference resonant frequency, thereby indicating an
3 increase in the mass of the substance disposed on the membrane.

1 8. The apparatus of claim 1, wherein said substance is present in a volume of a
2 volatile solution which is deposited on said membrane, the mass of the substance being
3 measured after the solution evaporates, leaving the substance on the membrane.

1 9. The apparatus of claim 8, further including a concentration determining
2 device for comparing the mass of the substance to the volume of the solution to determine
3 the concentration of the substance within the volume of the solution.

1 10. The apparatus of claim 9 wherein the substance is a non-volatile residue.

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1 11. The apparatus of claim 1 further including a display device connected to said
2 microprocessor for displaying the mass of said substance.

1 12. The apparatus of claim 1, further including a heating device for heating said
2 substance after it has been deposited on said membrane to evaporate moisture from said
3 substance, said frequency detection device determining the change in the reference resonant
4 frequency after the moisture is evaporated from said substance.

1 13. The apparatus of claim 12 further including a moisture content determining
2 device;
3 wherein the mass determining device determines the mass of the
4 substance after the substance is heated and the moisture content determining device
5 determines the moisture content of the substance by comparing the mass of the substance
6 before it is heated to the mass of the substance after it is heated.

1 14. The apparatus of claim 12 further including a boiling point determining
2 device;
3 wherein the heating device heats the substance with a temperature which is
4 increasing at a constant rate which causes the reference resonant frequency to increase at a
5 first rate as the mass of the substance decreases;
6 the frequency detection device monitors the rate of change of the reference
7 resonant frequency as the substance is heated; and

8 the boiling point determining device determines the boiling point of the
9 substance as the temperature when the rate of change of the reference resonant frequency
10 becomes greater than the first rate.

1 15. The apparatus of claim 1 wherein an increase in the reference resonant
2 frequency indicates a decrease in the mass of the substance on the membrane.

1 16. The apparatus of claim 1 including a plurality of sensors configured in an
2 array, each of the sensors being connected between said oscillator device and said frequency
3 detection device.

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1 17. A method for measuring the mass of a substance, the method comprising the
2 steps of:
3 driving a membrane of a sensor at a reference resonant frequency;
4 depositing the substance onto the membrane of the sensor;
5 measuring a shifted frequency within the membrane;
6 detecting a change of the shifted frequency from the reference resonant
7 frequency; and
8 determining the mass of the substance based on the change of the shifted
9 frequency from the reference resonant frequency.

1 18. The method of claim 17 wherein said depositing step comprises placing a
2 volume of volatile solution containing the substance on the membrane and allowing the
3 solution to evaporate, the substance thereby remaining on the membrane.

1 19. The method of claim 18, further comprising the step of comparing the mass
2 of the substance to the volume of the solution to obtain the concentration of the substance
3 within the solution.

1 20. The method of claim 17 further comprising the steps of:
2 heating the substance after the mass of the substance is determined to
3 evaporate any moisture in the substance;
4 measuring the post-heating frequency in the membrane after the heating

5 step;
6 detecting a change of the post-heating frequency from the shifted
7 frequency; and
8 determining the mass of the substance after the heating step based on
9 the change of the post heating frequency from the shifted frequency.

1 21. The method of claim 20 further comprising the step of determining the
2 moisture content of the substance before the heating step takes place, based on the
3 difference in the mass of the substance before the heating step and the mass of the
4 substance after the heating step.

1 22. The method of claim 17 wherein said depositing step comprises placing the
2 sensor in a fluid environment and allowing a volatile solution contained in the fluid
3 environment to collect on the membrane.

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An apparatus for measuring a change in the mass of a substance within the

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subnanogram range.

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